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Biological Pest Controls: Possibilities for Improved Implementation in Iowa

David B. Orr
Iowa State University

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David B. Orr
Temporary Assistant Professor
Department of Entomology

Introduction

Chemical insecticides are the standard means for reducing populations of insect pests in agricultural and horticultural settings. However, government regulations are restricting the use of a variety of pesticides for many agricultural uses. The requirement of registration for all pesticides labelled before 1984 has already resulted in the cancellation of approximately 20,000 pesticide registrations in 1989. In addition, pest resistance to insecticides (over 400 species), and an increased sensitivity in the general public to possible environmental and health hazards are forcing the agricultural industry to search for alternatives to chemical control.

Integrated Pest Management (IPM) offers the possibility of reduced pesticide use, and more sustainable pest management systems. Development of IPM programs has been described as proceeding through two stages (Van Dreische et al. 1990). Typically, Stage I IPM is concerned with making existing pesticide-dominated controls more efficient through the use of pest monitoring, establishment of economic injury levels, and use of reduced pesticide dosages. Adoption of these practices will typically lower pesticide use by 30-50%. However, further reduction in pesticide use through application of Stage I techniques alone becomes increasingly difficult. To lower the use of pesticides even further, IPM programs must include major non-chemical control measures such as biological control (Stage II IPM). Biological control typically involves the direct or indirect manipulation of natural enemies (predators, parasites, and pathogens) to suppress pest insect, weed, or plant pathogen populations through antagonistic species interactions (Garcia et al. 1988). Although biologically-based pest management methods such as development of pest-resistant plants, genetic manipulations (eg. sterile male releases), and the use of pheromones (eg. mating confusants) are sometimes included as biological controls, they will not be addressed here. The practice of biological control is usually considered to include pest suppression brought about by the purposeful manipulation of natural enemies by human activity. This contrasts with the so-called 'natural control' provided by biological control agents which occur naturally in the setting of interest (eg. agroecosystem).

There are three basic approaches to implementing biological control. The first approach is termed "classical biological control" and is usually used for pest species that have been accidentally introduced from one country to another. This typically involves the introduction of natural enemies which control a pest where that pest originated. Usually, this type of biological control is conducted by federal or state government agencies. A second type of biological control, called "augmentation", involves artificially increasing the numbers of natural enemies to give them a 'head start' on pest species to increase their chances of overtaking and suppressing pest populations. This is usually done by releasing laboratory-cultured biological control agents early in the growing season before pest numbers reach economic threshold levels. This is the type of biological control that is most commonly conducted on a commercial basis. The third basic type of biological control is called "conservation". This technique involves the adoption or maintenance of agricultural practices that conserve populations of natural enemies to maximize the natural control over pest populations they already provide. This type of biological control is usually done by individual growers to preserve natural enemies and their actions in a cropping system.

Biological Control in Iowa Crop Production

In this paper, I present available information on biological control agents and techniques which are commercially available (or potentially available) for use in Iowa crop production. I have restricted my presentation mainly to biological control of insects, but also include weed biocontrol where insects are the controlling agents. I have further restricted my topic to include only augmentative or classical approaches to biological control. Only those crop production systems for which biological control options are now available either in Iowa or elsewhere are presented.

Corn

To date, no effective biological control options are available for the corn rootworm. However, ICI International has shown recent interest in, and has obtained, an isolate of the fungus *Beauveria bassiana* which attacks corn rootworm.

There are, however, several biological control measures available (or potentially available) to growers for management of European corn borers. The bacterium *Bacillus thuringiensis* is the only biological control agent of the European corn borer which is commercially available in the United States. It is an excellent alternative to conventional insecticides for control of first generation European corn borer, providing control of borers equal to that of synthetic insecticides in a given year (Lynch et al. 1977ab). Successful control of second generation borers can be achieved with *B. thuringiensis,* however, as with synthetic insecticides, timing of application is vital (Lynch et al. 1977ab). Because *B. thuringiensis* does not directly harm beneficial insects, it will not disrupt any natural control they may provide over corn borers or other pests. *Bacillus thuringiensis* is currently used extensively in Nebraska, but is also used heavily by some Iowa seed corn producers.

Two other naturally-occuring pathogens can cause season-long epidemics in corn borer populations in Iowa (Lewis 1990a). These are the fungus *Beauveria bassiana,* and the microsporidian (similar to a protozoan) *Nosema pyrausta.*

Beauveria bassiana has been used in a number of efficacy trials, and in several cases provided upwards of 90% control of European corn borer (York 1958, Hsu 1973, Riba 1984). Studies conducted at the USDA-ARS Corn Insects Laboratory in Ankeny, Iowa have demonstrated season-long suppression of corn borers when the pathogen was applied to the whorl of the plant (Lewis 1990b).

Nosema pyrausta considerably reduces larval survival, adult life-span, egg production, and egg fertility of European corn borers both in the laboratory and in the field (Lewis 1990). It has been applied to corn as an aqueous spore suspension, controlling borer populations by as much as 48% (Lewis and Lynch 1978). Once in the corn borer population, it can be transmitted from one larva to the next, and can be transmitted in the eggs from one generation to the next. Only 25% of larvae in a population need be infected in order to start an epidemic (Lewis and Lynch 1978, Onstad and Maddox 1989).

Current limitations to commercialization of *B. bassiana* include lack of a commercially useful production (culturing) technique, short shelf-life, and high variability in efficacy. A major limitation to commercialization of *N. pyrausta* is the need for living insect hosts in which to rear the organisms. This could change in the future as 'biotechnologies' such as cell-culturing (currently being developed for baculoviruses) become more refined and widespread.

Perhaps the most promising arthropod biological control agents of the corn borer are the tiny stingless *Trichogramma* wasps. Unlike other parasitic wasps that attack corn borer larvae, *Trichogramma* kill the borer in the egg stage, before it can damage the plant. These wasps have been used to successfully control corn borers in both Europe (Hassan 1981, Raynaud and Crouzet 1985, Bigler and Brunetti 1986) and China (Cock 1985).

BASF France produces *Trichogramma* wasps for management of European corn borer on 30-40,000 acres of corn in France, and is currently increasing production. In North America, a native parasite of the corn borer, *T. nubilale,* has been studied in both Delaware (Kanour and Burbutis 1984) and Minnesota (Andow and Prokrym 1991). The Biological Control Laboratory of the North

Carolina Department of Agriculture conducted large-scale field experiments in 1988 and 1989 to develop production and release methods for *T. nubilale* against the corn borer, and demonstrated a reduction in corn borer damage in treated fields (Gou et al. 1988, 1989). Biofac Inc. provides *T. pretiosum* for commercial application by aircraft to several thousand acres of corn in west Texas to control Southwestern corn borers as well as corn earworm and fall armyworm. However, recent research at Michigan State University has shown that *T. pretiosum* and the two other *Trichogramma* species commercially available in the United States, *T. minutum* and *T. platneri,* do not attack European corn borer eggs in the laboratory.

Although *Trichogramma* wasps must be released several times during the egg-laying period of corn borer moths, the cost of three applications of *Trichogramma* is currently equal in cost to one application of insecticide in Europe. The Biological Control Laboratory of the North Carolina Department of Agriculture has refined production of *T. nubilale* on tobacco hornworm eggs to where costs were approximately $0.08/1000 insects (Gou et al. 1988). Cost of Trichogramma production will continue to decline, especially considering the joint CIBA-GEIGY/USDA efforts to develop artificial diets and mass-production technology at the Subtropical Agricultural Research Laboratory (S.A.R.L.) in Weslaco, Texas (King 1989).

The Biological Control Laboratory at Iowa State University, in conjunction with the USDA-ARS Corn Insects Laboratory at Ankeny, Iowa has initiated a two-year project, to start in 1991, to conduct a direct economic comparison of biological control and chemical control for management of the European corn borer. The pathogens *B. thuringiensis, B. bassiana,* and *N. pyrausta,* as well as *Trichogramma* wasps are to be included in the study. In addition, the use of a novel, very low-cost application technology (Remotely-Piloted Vehicles) will be demonstrated.

Pastures

Musk Thistle. This weed has been the target of attempts at biological control over approximately the last 10 years in Iowa. Several other neighboring states (including Nebraska and Missouri) have had some success with controlling the musk thistle by introducing and distributing the weevil *Rhinocyllus conicus.* The use of this weevil to control musk thistle requires patience on the part of growers/landowners since it usually takes the weevil 5-6 years before it becomes established at high enough densities to control thistle numbers. The weevils spread around very slowly in the environment, and in order to get them to other areas requires that people move the insects around. The current distribution efforts of the weevil in Iowa have been led to a large degree by growers (Sun. July 15, 1990, Des Moines Register), and ISU Agronomy and Entomology Extension. The weevils used in this program can be purchased commercially or obtained through a grower distribution source (Morris Wick, Taylor County, Iowa). The Iowa State University research on musk thistle biological control is currently being led by Robert G. Hartzler (Agronomy Extension, 515-294-1923).

Other weeds which occur in Iowa pasture, including leafy spurge and Canada thistle, have biological control agents which are commercially avialable through a single source (BCW, Bozeman, Montana).

Alfalfa

Biological control agents have been released against the alfalfa weevil in Iowa since 1975. Data reported by the USDA-APHIS-PPQ Biological Control Laboratory in Niles, MI indicate that 5 species of parasitic wasp have been recovered from Iowa. Although biocontrol agents are now present, little work has focussed on evaluating the effectiveness of these agents in suppressing populations of the weevil. One recent study (unpublished data, P.C. Kingsley, USDA-APHIS-PPQ, Bldg. 1398, OTIS Methods Dev. Ctr., OANGB, MA 02542) has shown that from 1981-1986 two of these parasites (*Bathyplectes curculionis, Microctonus aethiopoides)* were found in almost all fields sampled in Iowa and Missouri, and percent parasitism of both larval and adult weevils increased to approximately 35 and 55%, respectively. During the same period, peak alfalfa weevil larval densities dropped approximately 3-fold. Both larval and adult weevil densities were negatively correlated with percent parasitism, so that as percent parasitism within a given year increased, densities of larval weevils in that same year decreased. In addition, as percent parasitism of adult weevils in a given year increased, the density of larval weevils the following year was reduced. Although this work appears to have established that on a regional scale biological control has suppressed alfalfa weevil populations, more research is warranted, especially addressing the economic impact of this suppression.

Grasshoppers

There is one commercially produced biological control agent available for control of grasshoppers in the United States. The naturally-occurring pathogen *Nosema locustae* is usually applied as a wheat bran bait impregnated with pathogen spores. Field tests have shown that short-term control provided by *N. locustae* is not as good as that provided by chemical controls (Capinera and Hibbard 1987). Effects of *N. locustae* on grasshoppers are more chronic (long-term) and include reduced feeding activity, increased development time, increased mortality (particularly in physiologically stressed individuals), reduced reproduction, and increased transmission of the pathogen.

However, natural enemies of the grasshopper are numerous (Hantsbarger 1979), and their beneficial effect can be reduced through the use of synthetic insecticides (Lockwood et al. 1988). The preservation of these enemies as well as the effects of the pathogen in reducing reproduction and increasing transmission of the pathogen from one season to the next may be important in long-term management of grasshoppers (Lockwood and Debrey 1990).

Greenhouses

Perhaps the most well developed but least utilized biological control methods in Iowa are those for greenhouse pests. A recent survey conducted by USDA Iowa Agricultural Statistics, Des Moines, Iowa indicated that none of the greenhouse operations in Iowa are using biological control as part of their pest management practices. Given that pesticide use in greenhouses is one of the highest on a per acre basis of any agricultural system, much could be gained by incorporation of biological control into IPM programs for greenhouses.

Biological control agents have been shown by both public and private research worldwide to be very effective and economically advantageous against greenhouse pests (Hussey and Scopes 1985, Parella 1990, Van Lenteren and Woets 1988). Many of the major greenhouse pests can be managed using biological control agents and/or programs which are available from a large number of companies nationwide (see Fig. 1). The greenhouse environment is relatively enclosed and constant, making it highly amenable to biological control. However, greenhouses may have more than one crop present at any one time, and each crop may have multiple pest species. Therefore, even though biocontrols may be well worked out for these pests, they must be used as part of an IPM program that includes careful scouting, a knowledge of the pest species present, proper application of biological control agents, use of other non-chemical control methods (when available), and use of pesticides (only when necessary) that are compatible with biological control agents. As with any pest control method, biological control may not provide desired results if not used according to directions. Biocontrol/IPM companies which supply or produce these organisms may have either consulting services or literature available on their products and IPM programs. Unless growers have had extensive previous experience with biological control and/or IPM it is advisable to take advantage of consulting services to better ensure success.

Not all crops or all pests occurring in greenhouse situations have biological control programs developed for them yet. However, the insects listed below have very effective biological control/IPM programs developed for them on several of the crops on which they are major pests. The biological control agents listed are available from a large number of commercial suppliers both in the Midwest and around North America.

Greenhouse Whitefly. The most effective and commonly used biocontrol agent of this pest is a tiny stingless wasp, *Encarsia formosa*. These wasps will lay their eggs in whitefly scales, killing the whitefly and producing another adult wasp. This parasite can provide very effective suppression of whiteflies on a variety of plants both in greenhouses and 'interior plantscapes' (e.g. plants in malls, restaurants). Another agent available for whitefly control is *Delphastus* sp., a predator of whitefly eggs.

Spider Mites. Several species of predator mites are widely available which can suppress populations of spider mites under different environmental conditions. The most commonly sold of these is *Phytoseiulus persimilis,* but *P. longipes, Amblyseius californicus,* and *Metaseiulus occidentalis* are also available.

Leafminers. Two species of stingless wasps are sold through several sources for control of leafminer pest in greenhouses. *Dacnusa sibirica* and *Diglyphus isaea* are each used to control different species of leafminers.

Fungus Gnats. Two products are commercially available for control of both sciarid and mycetophilid fungus gnats. Both insect-feeding steinernematid nematodes and *Bacillus thuringiensis* var. *israeliensis* have been shown to effectively suppress fungus gnat populations. However, both of these agents may require repeated applications to be effective. Recent research by scientists in Agriculture Canada has resulted in development of a biological control system for fungus gnats on hydroponically-grown cucumbers using a single early-season inoculative release of the the soil-dwelling predatory mite *Geolaelaps* sp. nr. *aculeifer*. This predator does not appear to be commercially available currently.

Caterpillars. *Baccillus thuringiensis* products are widely available for worm control in greenhouse settings.

Thrips. Two predatory mites, *Amblyseius cucumeris,* and *A. barkeri* are commonly sold as biological control agents of thrips pests, in particular the Western flower thrips and onion thrips. Some biological control of western flower thrips has also been shown to occur with the soil-dwelling predatory mite *Geolaelaps* sp. nr. *aculeifer*.

Aphids. Although several types of insect predators are sold commercially for control of aphids in greenhouses, by far the most effective is the predatory midge *Aphidoletes aphidomyza,* available through several dealers in the United States.

Mealybugs. A predatory coccinellid beetle, *Cryptolaemus montrouzieri,* is widely sold for mealybug control in greenhouses and interiorscapes.

Stored Grain

Although stored grain pest management is not a part of production agriculture, I include it here because of the economic importance of losses to insects which attack stored grains, and the potential for biological control to play an important role in their management.

In May 1988, the US FDA seized a bin of rye grain at a mill in Texas to which biological control agents had been added (Stalcup 1990). The Food Drug and Cosmetics Act prohibits the addition of "filth" (which includes insects) to food. This was interpreted by the FDA to include beneficial insects used as biological control agents.

A draft proposal of a regulation to lift this ban has been scheduled to appear in the Federal Register in November, 1990. This proposal represents a compromise between the USDA, EPA and FDA that exempts beneficial insects from EPA tolerance levels for insect parts in grain. Since EPA does not regulate macroorganisms (predatory and parasitic insects, nematodes, etc.) as pesticides, an exception had to be made for this specific case. This regulation, as written, will apply only to raw bulk or bagged grain and to grain storage facilities.

Opposition appears to be developing to this draft proposal, and should surface during the 60 day public comment period following its publication. The Millers National Federation is strongly opposed to this exemption because they feel it will allow for an increase in insect fragments in grain. Two points have been raised to counter this argument: 1) beneficial insects will probably be used mainly as a preventative rather than a rescue treatment and be present in relatively low numbers, thereby meeting current tolerance levels for living insects in grain; 2) because beneficial insects are free-living (i.e. they do not remain inside grain) they should be easily screened out during regular processing at mills, since almost 100% of grain apparently goes through a very effective clean-up procedure to remove external dirt and insects during processing. Perhaps the only way this question will be satisfactorily resolved is through continued large-scale experimentation and/or adoption of biological control as a legal treatment of grains. If commercial application of biological control agents does result in levels of insect fragments and live insects in grain beyond current tolerance levels, it probably will not be competitive as a pest management tool and not be widely used.

Smaller-scale laboratory work by the USDA in Savannah, Georgia and Manhattan, Kansas indicates that biological control has the potential to work in large-scale settings. In experiments conducted in barrels, USDA found that *Sitophilus* weevils, Saw-toothed grain beetles, Indian meal moth, and almond moth populations could be reduced by 90-99% through the addition of beneficial insects. Similar, larger-scale experiments conducted at Savannah, Georgia gave poor results. These were attributed to insufficient application rates of beneficial insects, and a limited supply of beneficials. To date, only one long-term, large-scale controlled field experiment has been conducted to compare biological control with chemical control of stored grain pests. The results, reported in the Farm Journal (Stalcup 1990), indicated that use of predators and parasites (all six commercially available species) provided lower percent grain loss and greater added return over control than any of the three insecticide treatments (Atellic; Reldan + Diacon; Malathion). One of the insecticide treatments (Malathion) performed more poorly than did the untreated check. However, the cost of biological control was higher than any of the insecticide treatments. It should be noted that a constant source of very heavy infestation was present near the experimental area, and may account for the poor performance of Malathion and the need for the relatively high number of beneficial insects used. Although the results are promising, the scientists conducting the experiment indicate that more experiments are needed to refine such factors as numbers of beneficials to apply. As with other biological control agents, the cost of production of predators and parasites of stored grain pests should decrease as production technology improves and demand increases. Passage of the proposed exemption regulation discussed above would allow legal conduct (without the extremely high cost of purchasing all the grain involved) of further large-scale experiments planned by the USDA.

Data obtained from Biofac, Inc. (collected jointly by customers and Biofac) indicate that the average reduction in pest numbers ("Lesser grain borer; *Tribolium;* Weevils; *Cryptolestes;* moths") over 3 months at 9 elevators was 94.5%. Biofac has apparently developed its own IPM systems which are currently in the process of being patented, and sells biological control agents which will attack 29 different stored grain pest species. It is important to note that as with any biological control program, the beneficial organisms used for stored grain pest management are not as simple to use as insecticides, and require knowledgeable and careful application. Full use should be made of consulting services, and informed decisions should be made regarding use of biological control.

The following list presents general classes of pests and the natural enemies sold for their control:

1) Weevils - the stingless wasps *Anisopteromalus calandrae*

and *Choetospila elegans,* the parasitic mite *Pyemotes tritici*.

2) Moths/borers - stingless wasps *Bracon hebetor* and *Trichogramma pretiosum,* the generalist predator *Xylocoris flavipes,* and the mite *Pyemotes tritici*.

3) Beetles - the stingless wasp *Choetospila elegans,* the generalist predator *Xylocoris flavipes,* and the mite *Pyemotes tritici*.

Application of Biological Control Agents

Often, when large-scale distribution of biological control agents is not necessary, application is done by hand without any specialized equipment. In biological control programs in greenhouses for example, biological control agents may be released by hand by sprinkling organisms (in a carrier) from small containers, or placing the containers in the cropping situation. Packaging of biological control agents has progressed to where there may be little difference between a bottle of insecticide and one containing living organisms. Some companies have registered trademarks for the living organisms they sell.

In situations such as augmentative releases, application technology has been developed to accomodate biological control agents. In a number of cases, beneficial insects can be mixed in a granular type formulation. This usually involves mixing a resting stage (such as eggs or pupae of the beneficial organism) with material such as corn grits or bran for example. Application of materials in this format is then a relatively simple task. There are commercially available hoppers which can be mounted in or on aircraft, and numerous custom-designed versions designed by the individuals using them.

Full-scale aircraft (airplanes and helicopters) have been successfully used to apply biological control agents both commercially and experimentally in North America and Europe (Balbanova 1983, Carrow et al. 1991, Grossman 1990, Lagutochkin 1987). These include commercial airplanes and helicopters of a type used previously for insecticide application, and light civilian aircraft, both slightly modified with specialized hoppers. The hoppers may be refrigerated and may have agitators, and biological control organisms are usually dispensed by gravity-feed.

Smaller-scale Remotely-Piloted Vehicles (RPV's) have been designed (Gottwald & Tedders 1986) and used experimentally (Grossman 1990, Tedders & Gottwald 1986) for releasing insect predators, parasites, and diseases. The use of RPV's for this purpose presents several distinct advantages over standard aircraft (Gottwald & Tedders 1986, Tedders & Gottwald 1986). Perhaps the most important of these would be the reduction in cost to Pest Control Applicators, and susequently growers. One-third- scale RPV's capable of carrying commercially useful loads of biological control agents cost less than $2000, making them approximately 1/100th the cost of full-scale aircraft, and a fraction the cost of ground-operated spray equipment. Insurance costs on the plane (particularly if it is only used to deliver biological control agents) are substantially reduced (Grossman 1990). In addition, pilot safety is not a factor with RPV's, and they can be flown slowly enough so that mortality of biological control agents is not increased as a result of release from the aircraft.

The Biological Control Industry

In examining the biological control industry, I have not included the relatively large corporations which specialize in manufacture of microbial insecticides, because of the very wide availability of products such as *B. thuringiensis*. Instead, I have concentrated on those companies which provide, for the most part, macroorganisms (predators, parasites, nematodes).

The available information indicates that there are currently 59 companies in the United States that offer at least one type of biological control product and/or service (Fig. 1). In addition, there are three companies in Canada (1 in British Columbia, 2 in Ontario) which specialize in biological control. Most of these companies sell products for control of insects. Only two of which I am aware sell products for biological control of weeds (BCW, Bozeman, Montana: Bio Collect, Oakland, California). Several sell agents for biological control of a plant pathogen, crown gall. There is virtually no production of these biological control organisms in the Midwest (Fig. 2). Of the three companies that are listed as producers in Figure 2, one field-collects praying mantid egg cases from outdoors, and other produces praying mantids and soldier bugs in an insectary. Most of the Midwest biological control suppliers purchase their products wholesale from, or are distributors for, large insectaries in either California or Europe.

The biological control production and supply industry has until quite recently been more or less a cottage industry, with numerous small businesses meeting a relatively modest demand. However, this situation is changing rapidly. Increasing size and scope of some North American biological control companies, in some cases spurred by investment from other North American and European companies, is resulting in increased product availability, as well as private research and development. Substantially increased R&D by large agrichemical corporations is being directed towards several species of parasites, predators, and pathogens. Public pressure will probably continue to result in proposals such as Proposition 128 (the so-called Big Green initiative) recently voted on (but defeated) in California. This activity combined with increasing government regulations and cost of new agrichemical product development is, and will continue to, result in increased demand for biological control products and services for pest management programs. Many of the companies supplying biological control agents are geared toward retail sales for home gardeners and other small-scale situations, and may also provide organic gardening products and information. Others are geared towards larger commercial operations, and may sell only wholesale. Companies that specialize in biological control and/or IPM services probably have the most experience with and knowledge of biological control. Since biological control can be considerably more complicated to use than synthetic pesticides, it is wise to have good advice from experienced consultants when designing pest management strategies to ensure the maximum chances for success.

The level of public education about biological control may be reflected in consumer demand, and types of biological control agents provided by a portion (aimed at the home gardening market) of the biological control industry. In a survey of household pesticide use in Indiana, 72% of those interviewed knew about beneficial insects (Bennett et al. 1983). However, the most commonly identified beneficial insects were praying mantids and lady beetles. These insects, although correctly described as beneficial insects, are usually too general in their feeding habits to provide useful biological control in many settings. Consumer demand for these types of insects is reflected in the product rating and company profile presented in Figure 3. A chronic lack of research funding in public biological control research has meant that in some cases, research has not kept up with industry or public demand for biological control products and services. This may mean that in some cases, biocontrol products are offered commercially before having been thoroughly researched. This could provide opportunities for lower quality biological control agents or programs to be marketed. However, it is also prompting an increasing amount of research activity by private industry. In the end, if the consumer makes an informed choice when selecting biological control products, and makes full use of available consulting services, use of biological control can be an effective alternative to pesticides for management of some insect and weed pests.

Where to Get Further Information

It should again be noted that this report has been restricted to biological control options available for agricultural concerns in Iowa only. There are a number of other biological control products commercially available for managing pest populations in a variety of settings.

Published lists are available providing addresses, telephone numbers, and product listings for the various companies which produce and/or supply biological control organisms. The most complete of these is a pamphlet put out by the California

Department of Food and Agriculture (Biological Control Services Program, 3288 Meadowview Road, Sacramento, CA 95832) and updated every four to five years; the latest update was published in 1989. Lists have also appeared in trade journals such as the July 1990 issue of Ag Consultant and April 1990 issue of IPM Practitioner. Newer companies, products, and a company offering agents for the biological control of weeds do not appear on these lists. There is a newly-formed trade organization, representing the production side of this industry, named the Association of Natural Bio-Control Producers (ANBP) whose current president is Synthia Penn (916-472-3715, 245 Oak Run Rd., Oak Run, CA 96069). The Biological Control Coordinator (Norman Leppla, 512-969-1541) in USDA-APHIS has recently compiled a survey of biological control producers and suppliers in the United States.

For complete information and recommendations about biological control in Iowa, interested parties may contact the author (515-294-7489), the biological control specialist (John J. Obrycki, 515-294-8622) in the Department of Entomology, Iowa State University, Ames, IA 50011 or the Insect Pathologist (Leslie C. Lewis, 515-964-6664) at the USDA-ARS Corn Insects Research Laboratory, Ankeny, Iowa 50021. Other sources for biological control information are the State Entomologist (Carl Carlson), and the Iowa State Extension Service.

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Figure 1 - Distribution of suppliers of biological control organisms in the United States.

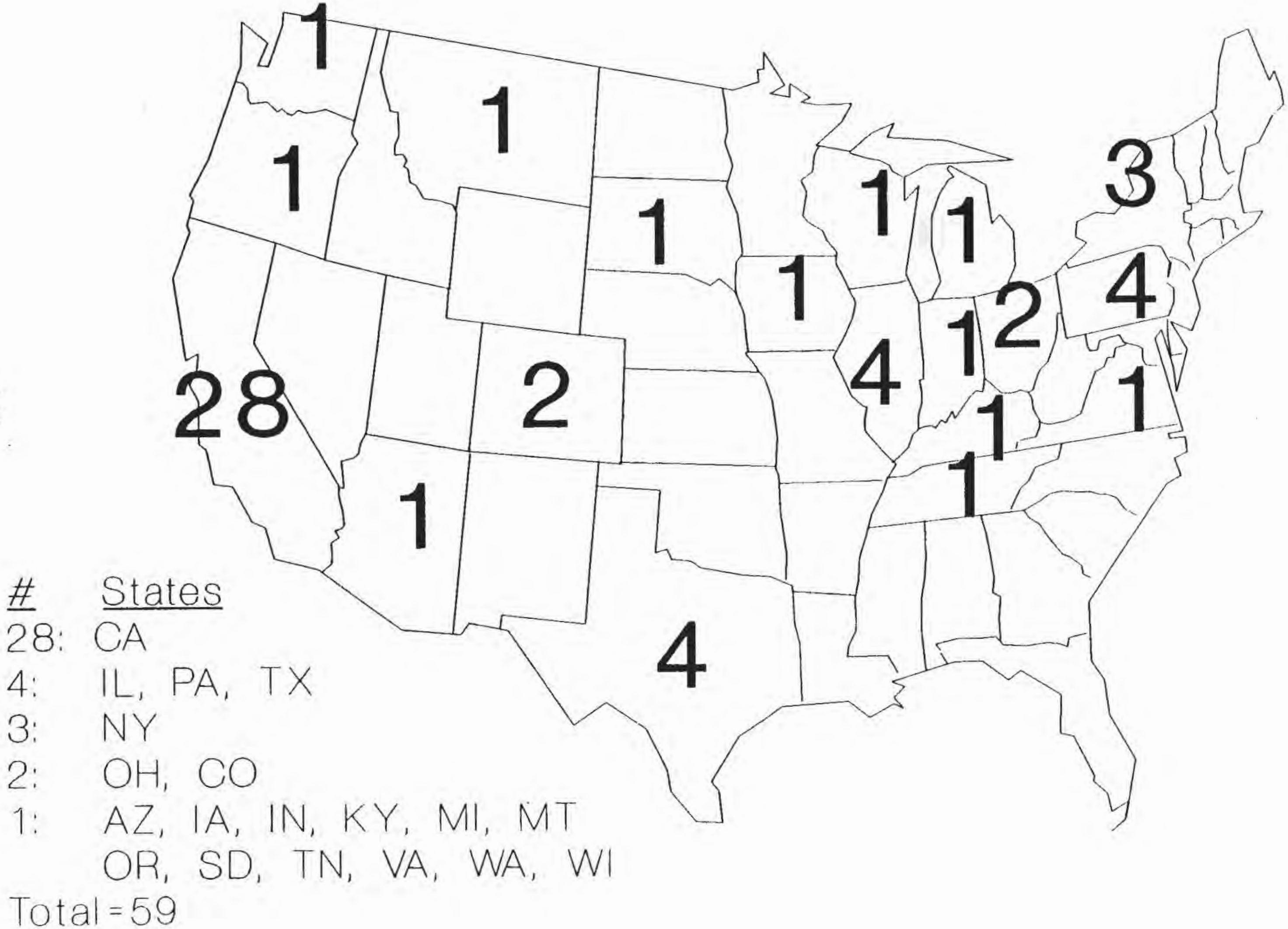

Figure 2 - Suppliers and producers of biological control agents in the Midwest. S=supplier, P=producer; R=retail, W=wholesale. Note that (P) indicates field-collected praying mantids.

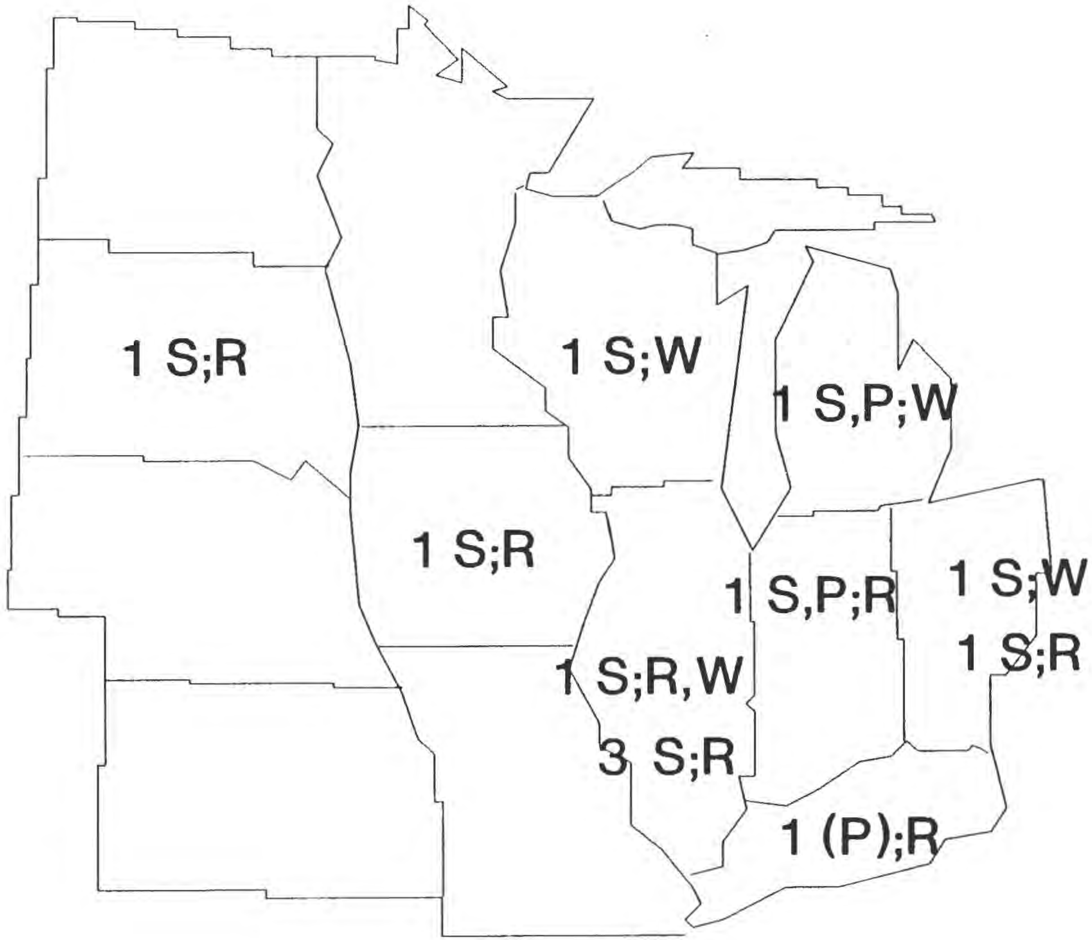

Figure 3 - Profile of biological control suppliers and products offered in the Midwest. Product Rating: 0=ineffective; 1=has potential, needs further research; 2=partially effective; 3=very effective.